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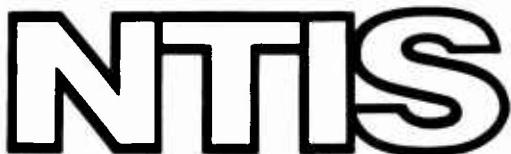
**THE FEASIBILITY OF CONCENTRATING/SEPARATING DILUTE
NITROCELLULOSE ACID WASTEWATERS BY REVERSE OSMOSIS**

Vincent J. Ciccone

**Army Mobility Equipment Research and Development
Center
Fort Belvoir, Virginia**

November 1974

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) In cooperation with Picatinny Arsenal's Pollution Abatement Program and in response to their Procurement/Work Directive PRON: GG-325205-01-GG-EF, a feasibility study focused on the application of membrane technology for the concentration and/or separation of dilute acid wastewaters was conducted by the Sanitary Sciences Division, USAMERDC. Preliminary laboratory investigations using commercially available cellulose-acetate reverse osmosis (RO) membranes were conducted at Radford Army Ammunition Plant (RAAP) by plant personnel. The objective of this study was to (Continued)		

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concentrate the dilute acids as a unit process toward abating the nitrate pollution problem or as an intermediate step in the recovery of the nitric and sulphuric acids. Results of these preliminary investigations indicated that RO was a potential candidate for larger scale application and, therefore, more detailed work was warranted. Of special interest was the development of an acid-resistant membrane to counter the susceptibility of cellulose-acetate to hydrolysis when continuously exposed in an acidic environment.

Based on the data obtained in the laboratory phase of this study and subject to the data generated in the pilot plant phase, the following conclusions appear valid:

- a. The application of cellulose-acetate and modified sulfonated polyphenylene oxide RO membranes as a unit process in the treatment of dilute acid wastewaters generated at RAAP is technically feasible.
- b. The concentration of nitric and sulphuric acid at acceptable rates for engineering scale-up using RO is feasible and attainable.
- c. The permeation or flux rates attainable in the treatment of RAAP acid wastewaters are acceptable for engineering scale-up.
- d. Hydrolysis of the cellulose-acetate membrane did not significantly impair the performance characteristics of the RO modules.
- e. Acidic corrosion of the metallic components of the RO system can introduce operational problems that will significantly interfere with the rejection and flux rates of the RO membranes.
- f. Continuation of the program into a Phase II RO pilot plant operation located at RAAP for on-site evaluation and performance documentation and/or verification is justified.

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PREFACE

The investigation covered in this report was conducted under the authority of Picatinny Arsenal Pollution Abatement Program Procurement/Work Directive PRON: GG-325205-01-GG-EF. The period covered is from August 1972 to June 1974.

The work was accomplished by LTC Vincent J. Ciccone under the supervision of Richard P. Schmitt, Chief, Sanitary Sciences Division (SSD) and Kennedy K. Harris, Chief, Military Technology Department. Data acquisition was accomplished by James M. McCann and Robert G. Ross of SSD. Data analysis was carried out by Genevieve Meyer; David B. Scott, Jr.; and Arthur L. Nickless of the Analysis and Programs Division, USAMERDC.

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THE FEASIBILITY OF CONCENTRATING/SEPARATING DILUTE NITROCELLULOSE ACID WASTEWATERS BY REVERSE OSMOSIS

I. INTRODUCTION

1. Subject. This report covers a Picatinny Arsenal-financed study of the feasibility of membrane technology for the concentration and/or separation of dilute acid wastewaters.

2. Background. Acid wastewaters are generated in the manufacture of explosives and propellants. The primary pollutants are nitrates in the form of nitric acid and sulfates in the form of sulfuric acid. Nitric acid is generally the nitrating agent used in the production of such commodities as trinitrotoluene (TNT), nitroglycerin (NG), nitrocellulose (NC), and nitroguanidine. Sulfuric acid smooths the nitration reaction and absorbs the water released by esterification. Pollution results from the numerous rinsings following the nitration step and also from spills, leaks, and washdown operations from the manufacturing processes involved in the production of nitric acid and inorganic nitrates.

II. INVESTIGATION

3. Technical Approach. The bench scale phase of this project using commercially available cellulose-acetate RO membranes was designed to demonstrate the feasibility of concentrating/separating the spent acid wastewaters. The wastewater used in the experimental setup was a 3000-gallon batch taken from RAAP's Nitrocellulose Boiling Tub Pit. Acid concentrations were as shown in Table 1. The experiment using a process evaluation bench scale model with a single spiral-wound module was designed as noted in Figure 1. No pretreatment, such as pH adjustment, was attempted, nor was it deemed necessary to filter the water prior to the RO process. Concurrently with the in-house work being conducted at USAMERIDC, a contract was awarded to the Direct Energy Conversion Division, General Electric Company, Lynn, Massachusetts to constitute, cast, and fabricate modified sulfonated polyphenylene oxide (SPPO) RO membranes which in previous G.E. work had indicated favorable resistance to low pH environments. Time framings on both efforts were such that July 1974 was estimated for on-site pilot plant studies (at RAAP) to confirm findings obtained in the laboratories. The scale of the pilot plant operations was designed to be approximately 1000 gallons per day (gpd) product water.

**Table 1. Acid Composition of Wastewater from
Nitrocellulose Area - Boiling Tub Pt
Radford Army Ammunition Plant***

Concentration (ppm)		
Nitrates (NO ₃)	Sulfates (SO ₄)	pH
3200	5400	1.4

*Collected July 1973

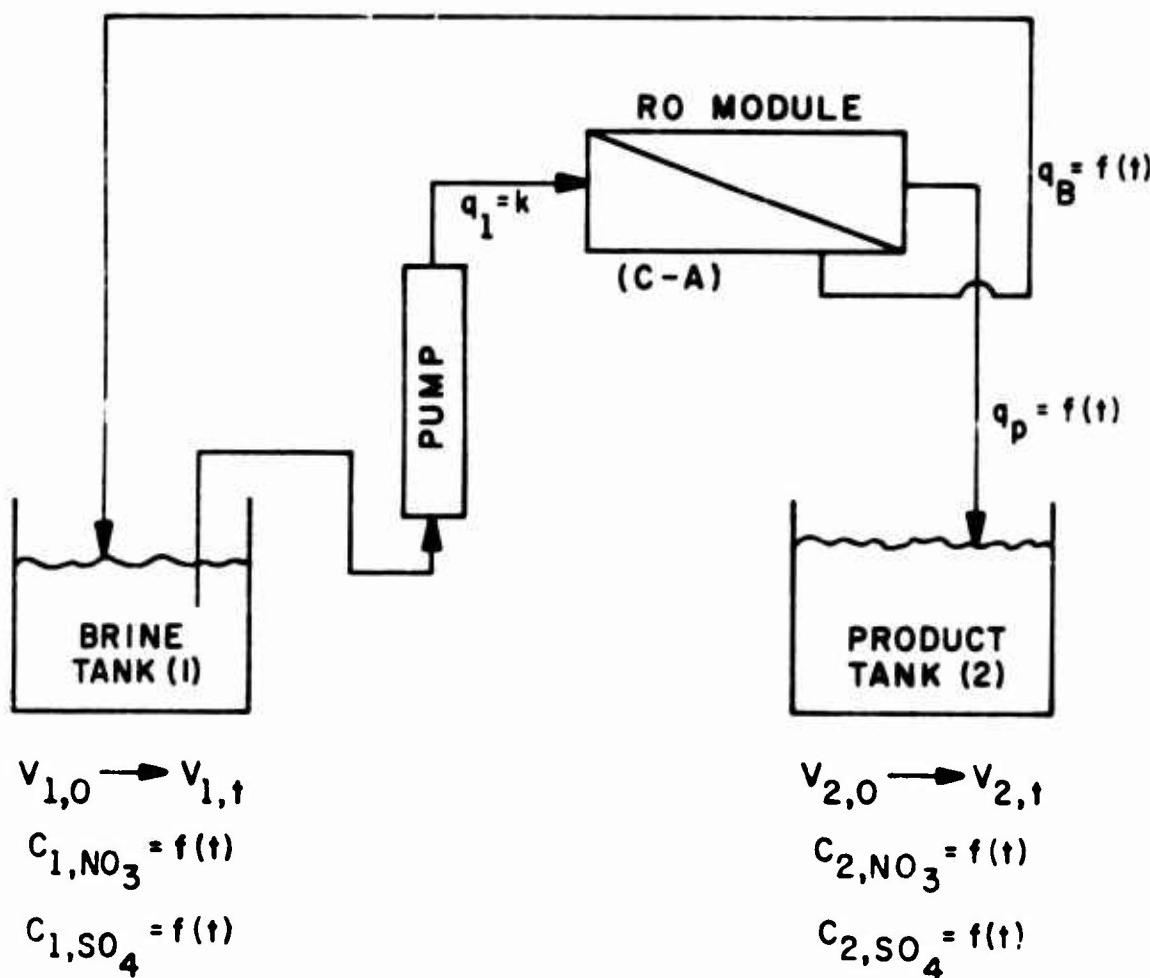


Figure 1. Simplified schematic flow diagram for laboratory setup.

The modeling mathematics of the experiment are detailed in Appendix A. This model was subsequently coded in FORTRAN by the Analysis & Programming Division (USAMERDC) for use on USAMERDC's CDC 6600 digital computer. The program appears as Appendix B. Output is available in the printed mode and as CALCOMP plots and prints.

All sample collection and chemical analyses were accomplished by personnel of the SSD, USAMERDC. Nitrate determinations were made using a nitrate specific ion electrode probe in conjunction with an expanded scale meter. Sulfate concentrations were determined using a Hach DR/2 spectrophotometer and the turbidimetric method found in APHA Standard Methods, 13th edition.

4. Results. The observed data for this phase of the project are shown in Tables 2 through 6. Nitrate concentrations are designated as IMPURITY 1, sulfates as IMPURITY 2. The product flow rate is reported in Table 6, where the change in volume of the product tank is measured as a function of time. The collected data were analyzed and plotted using computer curve fitting techniques and programs. Calcomp plots were produced and are shown as Figures 2 through 4.

A second-order polynomial curve was used as the data fitting model for the data reported in Tables 2 through 6. The statistical parameters associated with these fits were calculated and are reported in the computer printout attached as Appendix C.

Calculated engineering design parameters, based on second-order curve fits to the observed data, are shown in Table 7.

Calculated flux rates as a function of time are shown in Table 8 and the cartesian coordinate graph of these values in Figure 8.

The observed data as reported by General Electric Company regarding the modified SPPO membrane performance are shown in Table 9.

Figure 5 shows typical acid wastewater as generated at RAAP.

Figure 6 shows a typical section of cellulose acetate RO membrane cut from the actual module used in this study.

Figure 7 shows a typical 2-inch-diameter SPPO RO module mounted on a bench scale experimental setup.

Table 2. Impurity No. 1 (Nitrates), Brine Tank Concentration vs Time*

Time (hr)	Nitrates Conc. (ppm)				
	Run No.				
	1	2	3	4	5
0	2080	2550	2330	2500	2180
2	2080	2500	2310	**	**
4	2030	2460	2360	2420	**
6	2027	**	2190	**	**
8	*	2490	2200	2280	**
10	*	**	2160	**	**
12	**	**	2175	2290	**
14	**	**	2155	**	**
16	**	2320	1990	2190	**
18	**	**	**	1825	**
20	**	2160	1700	**	**
22	**	*	*	1495	**
24	**	*	*	*	**
26	*	*	*	*	1310

*Cellulose acetate membrane.

**No data collected at this point.

Table 3. Impurity No. 2 (Sulfates), Brine Tank Concentration vs Time*

Time (hr)	Sulfates Conc. (ppm)				
	Run No.				
	1	2	3	4	5
0	3800	5900	5800	6400	6300
2	4100	6300	6500	**	**
4	5600	6200	6600	6900	**
6	5800	**	8500	**	**
8	*	6600	8500	7900	**
10	**	**	9000	**	**
12	**	**	9600	9100	**
14	**	**	8800	**	**
16	**	9800	9000	11,000	**
18	**	**	**	14,000	**
20	**	12,000	10,500	**	**
22	**	*	*	17,000	**
24	**	*	*	*	**
26	*	*	*	*	17,500

*Cellulose acetate membrane.

**No data collected at this point.

Table 4. Impurity No. 1 (Nitrates), Product Tank Concentration vs Time*

Time (hr)	Nitrates Conc. (ppm)				
	1	2	3	4	5
0	0	0	0	0	0
2	2180	2700	2590	**	2180
4	2170	2730	2610	2850	**
6	2028	**	2720	**	**
8	*	2800	2670	2850	**
10	**	**	2640	**	**
12	**	**	2650	2720	**
14	**	**	2640	**	**
16	**	2750	2600	2840	**
18	**	**	**	2790	**
20	**	2860	2210	**	**
22	**	*	*	2770	**
24	**	*	*	*	**
26	*	*	*	*	2930

*Cellulose-acetate membrane.

**No data collected at this point.

Table 5. Impurity No. 2 (Sulfates), Product Tank Concentration vs Time*

Time (hr)	Sulfates Conc. (ppm)				
	1	2	3	4	5
0	0	0	0	0	0
2	300	700	500	**	**
4	200	400	460	680	**
6	200	**	480	**	**
8	*	600	470	620	**
10	**	**	510	**	**
12	**	**	560	820	**
14	**	**	540	**	**
16	**	480	500	850	**
18	**	**	**	800	**
20	**	550	690	**	**
22	**	*	*	950	**
24	**	*	*	*	**
26	*	*	*	*	1750

*Cellulose-acetate membrane.

**No data collected at this point.

Table 6. Volume in Product Tank vs Time

Time (hr)	Volume in Gallons				
	Run No.				
1	2	3	4	5	
0	0	0	0	0	0
2	22.5	23.8	61.0	**	25.0
4	45.0	45.0	88.0	35.0	**
6	57.5	**	104.0	**	**
8	*	70.0	119.0	85.0	**
10	**	**	144.0	**	**
12	**	**	163.0	121.0	**
14	**	**	182.0	**	**
16	**	145.0	198.0	160.0	180.0
18	**	**	**	200.0	211.0
20	**	185.5	240.0	**	237.0
22	*	*	*	235.0	242.0

* Cellulose-acetate membrane.

** No data collected at this point.

Table 7. Calculated Values for Engineering Design Parameters*

Parameter	Time (hr)		Remarks
	0	20	
Volume 1 (gallons)	345	125*	Brine Tank
Volume 2 (gallons)	0	212	$V_2 = -1.13t^2 + 13t + 3.5$ Product Tank
CSO ₄ (ppm)	5640	11096	$CSO_4 = 13t^2 + 11t + 5676$ [Brine]
CNO ₃ (ppm)	2330	1860	$CNO_3 = -2t^2 + 19t + 2280$ [Tank]
CSO ₄ (ppm)	5640	500**	Product Tank
CNO ₃ (ppm)	0	2535**	
pH	1.3**	1.0**	Brine Tank
pH	0	1.6**	Product Tank

* Cellulose-acetate membrane.

** As observed and recorded - average value.

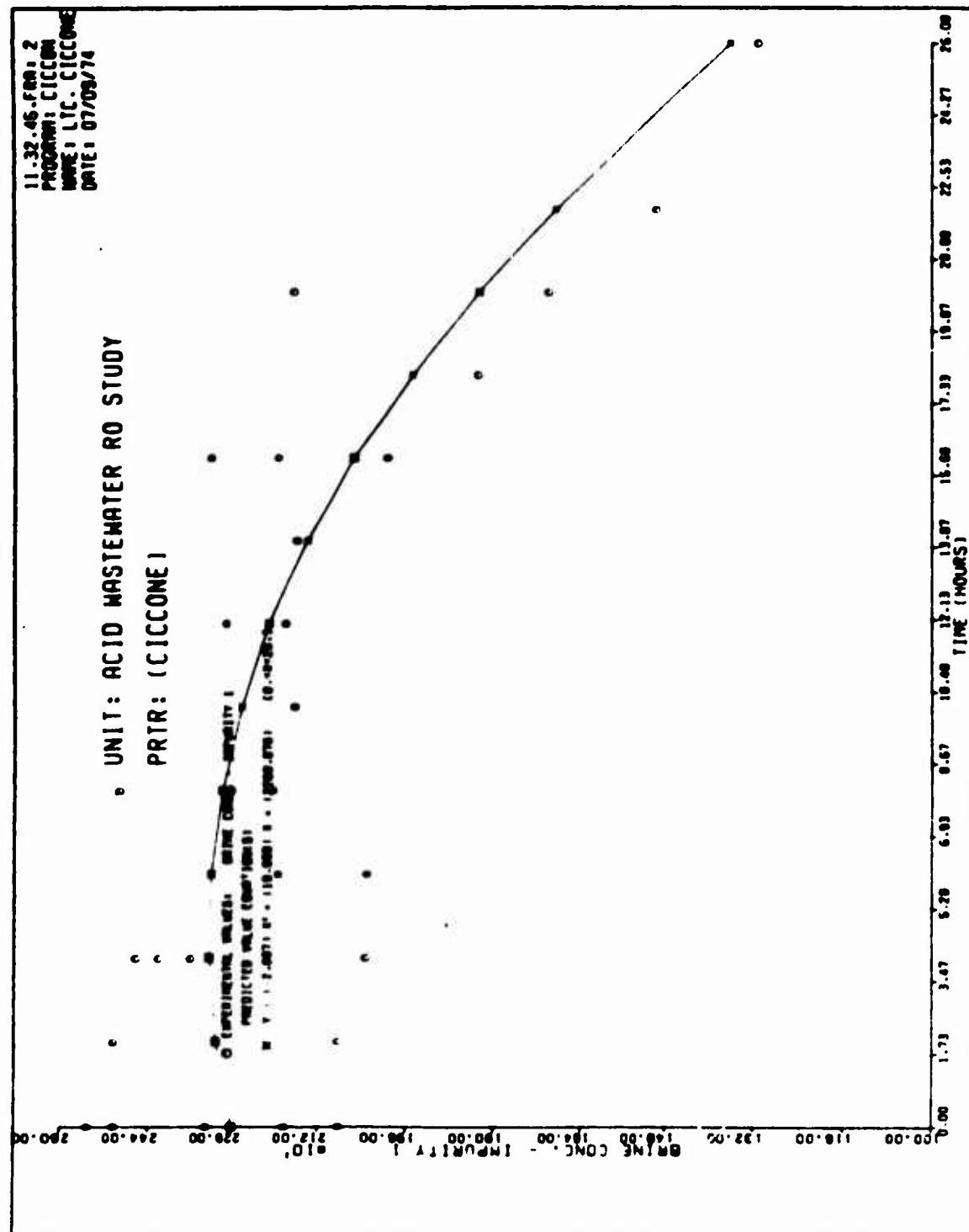


Figure 2. Concentration of nitrates in brine tank vs time.

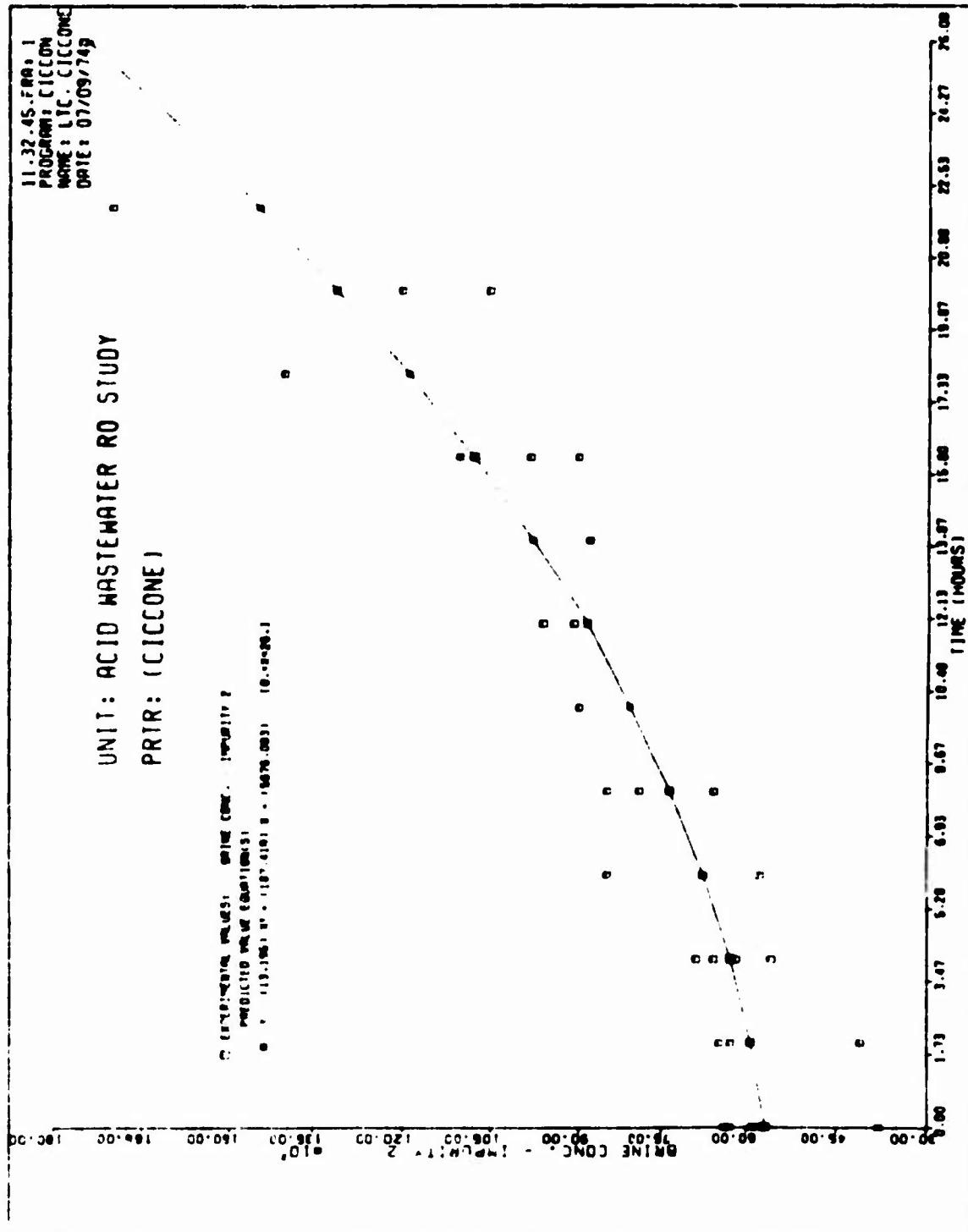


Figure 3. Concentration of sulfates in brine tank vs time.

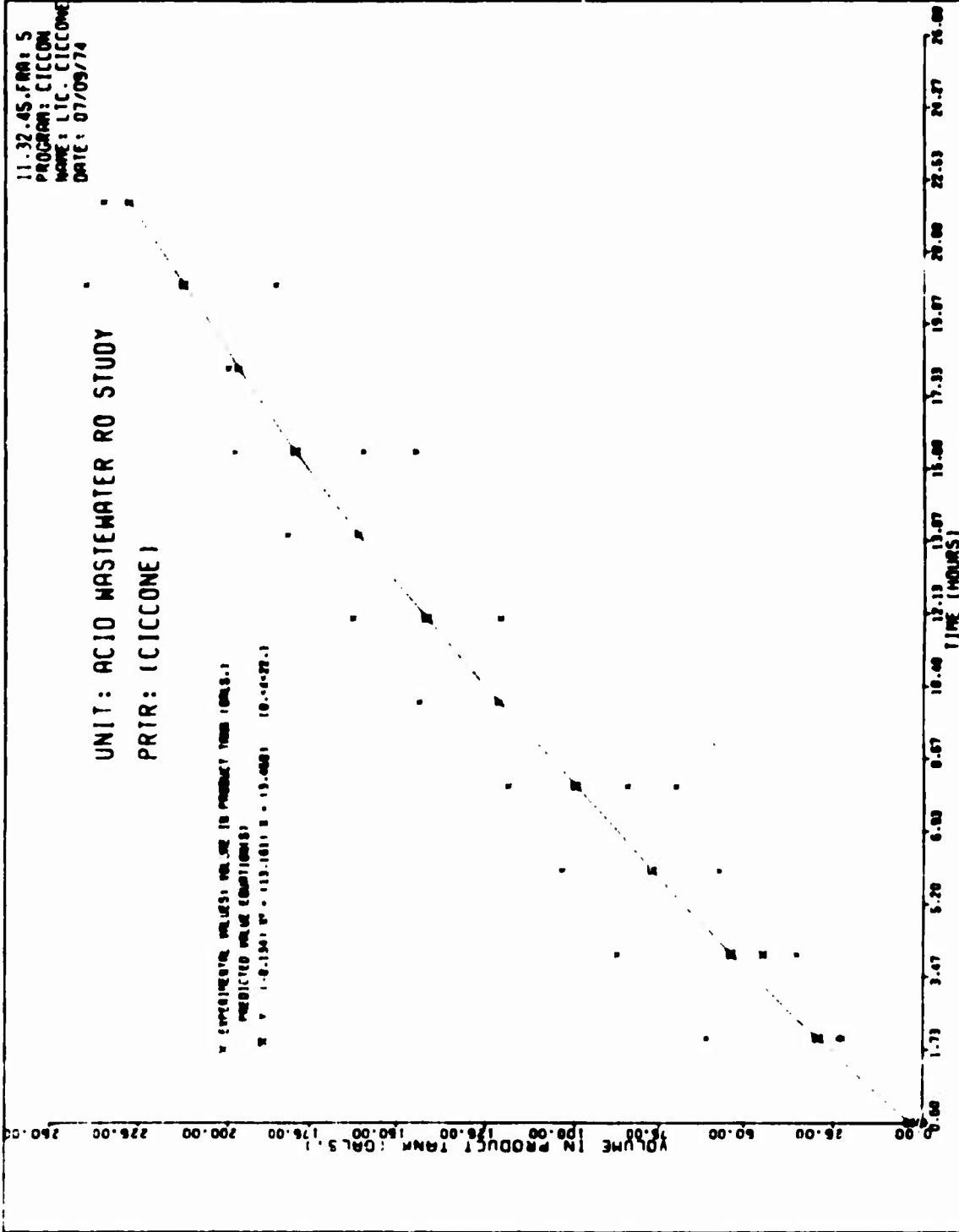


Figure 4. Volume in product tank vs time.

**Table 8. Calculated Module Product Ion Rate
(gph & GF²D)
(Based on Second-Order Fitted Curve)**

$$V_2 = -0.13t^2 + 13t + 3.5$$

$$\frac{dV_2}{dt} = -0.26t + 13$$

Time (hr)	Production Rate	
	gph	GF ² D*
0	13.00	9.49
2	12.50	9.13
4	11.96	8.73
6	11.44	8.35
8	10.92	7.97
10	10.40	7.59
12	9.88	7.21
14	9.36	6.83
16	8.84	6.45
18	8.32	6.07
20	7.80	5.70

*Module surface area = 33 S.F.

Table 9. Modified Sulfonated Polyphenylene Oxide Membrane Evaluation

Membrane Sample No.	Performance*		
	Test Time (hr)	Flux (GF ² D)	Rejection (%)
1	24	30	87
2	20	11	90
3	17	12	90

Experimental Conditions Were:

Feed: 3000 ppm acid (2000 H₂SO₄, 1000 HNO₃)

Press: 600 psi

Temp: 74°F - 80°F

* As reported by General Electric Co. under Contract DA AK02-73-C-0407 with USAMERDC.



Figure 5. Typical acid wastewater from RAAP.

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Figure 6. Typical section of cellulose acetate RO membrane after exposure to acid wastewater.

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Figure 7. Typical 2-inch-diameter SPPO module – in bench scale setup.

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III. DISCUSSION

5. Discussion. The cellulose acetate membrane experiment described earlier was designed to yield data which could be representative of the module behavior with respect to its ability to reject both acid species and to establish its water production or flux rate. The five runs, as noted in Tables 2 through 6, essentially were discrete repetitions of the same experiment. An objective in producing these data was to structure it into a form which could be acceptable for engineering design of a larger scaled-up system. The second-order curves obtained provide these engineering design data when considering the rate at which the acid species are being affected. Figures 2 and 3 show the nitrate and sulfate concentrations in the brine tank as functions of time. The rates at which these are changing with respect to time are easily obtained by taking the first derivative of the fitted curve; i.e., dC/dt . In this manner, the rates may be computed for any point in time within the bounds of the experiment. Since we are ultimately interested in designing a fullscale plant, practicality dictates that operation stay within a 24-hour period. Hence, the upper bound on the curve is valid (i.e., less than 24 hours) and differentiation of the curve within these time limits yields rates which may be interpreted as truly indicative of the module performance. This technique when applied to the permeate or flux rate (i.e., dV_2/dt , Figure 4) of the module integrates the rate over time, giving a more accurate estimate of this variable as compared to a grab sampling manner of estimation. It is noted in this case that flux rate may be described as an unsteady rather than a steady state condition, and hence time averaging or smoothing is necessary to account for the inherent variations. Given this derived empirical equation, one may then estimate flux at any given point over the time horizon of interest; i.e., within a 24-hour period. Simultaneously, the rate of concentration (or loss) of the particular acid species may also be calculated.

Table 7 shows the calculated values for the parameters of interest, after a 20-hour continuous run, for a single RO spiral-wound module. This performance behavior was encouraging, especially in light of the pH values. Hydrolysis of the membrane is a potential failure mode, and it was expected by this investigator that hydrolysis would occur. A rapid means of detecting gross hydrolysis was used throughout the data collection phase. This involved rinsing the module with tap water and determining the total dissolved solids (TDS) values of the inlet, product, and retentate streams using a dissolved solids meter. In each case, the reported TDS rejection rate was recorded at (on the average) approximately 90 percent. This indicated that gross hydrolysis had not occurred. A possible explanation for this favorable behavior may lie in part in the operational mode followed throughout the experiment. That is, after approximately every 8 hours of continuous operation, a short period of fresh water flushing was accomplished, which in effect tended to modify the membrane pH—a critical condition for hydrolysis to occur. To assume that the membrane pH is consistent with that of the brine or permeate fluids

is not necessarily correct. This assumption needs further verification and its documentation is beyond the scope of this work. The data observed here indicate that there may be an inconsistency in the membrane-fluid pH relationship or that at least a time-reaction element condition exists and it plays a significant role in that relationship.

In reviewing the production or flux rates of the module, evaluating the variable dV_2/dt for selected t values gives an indication of the commonly observed classical "fouling" behavior. The exact mechanism or cause for this phenomenon will not be pursued here, but suffice it to say that the primary cause was believed to be colloidal materials and ferric oxides. The colloidal materials may have been present in the original wastewaters, while the iron oxides may have originated within the experimental system due to the corrosive activity of the acids upon the metallic components of the setup. In any case, the noteworthy item is that Figure 8 is representative of statistically analyzed values which indicate the recoverability of the flux after repeated experiments or exposures. That is, the function may be interpreted as being a predictor for a reversible type degradation of flux overtime (20 hours) when the operational mode includes periodic flushing with a fresh water. Given this empirical "engineering data" and that shown in Table 7, the problem of a properly designed RO system capable of treating acid wastewaters can be approached with an encouraging degree of confidence.

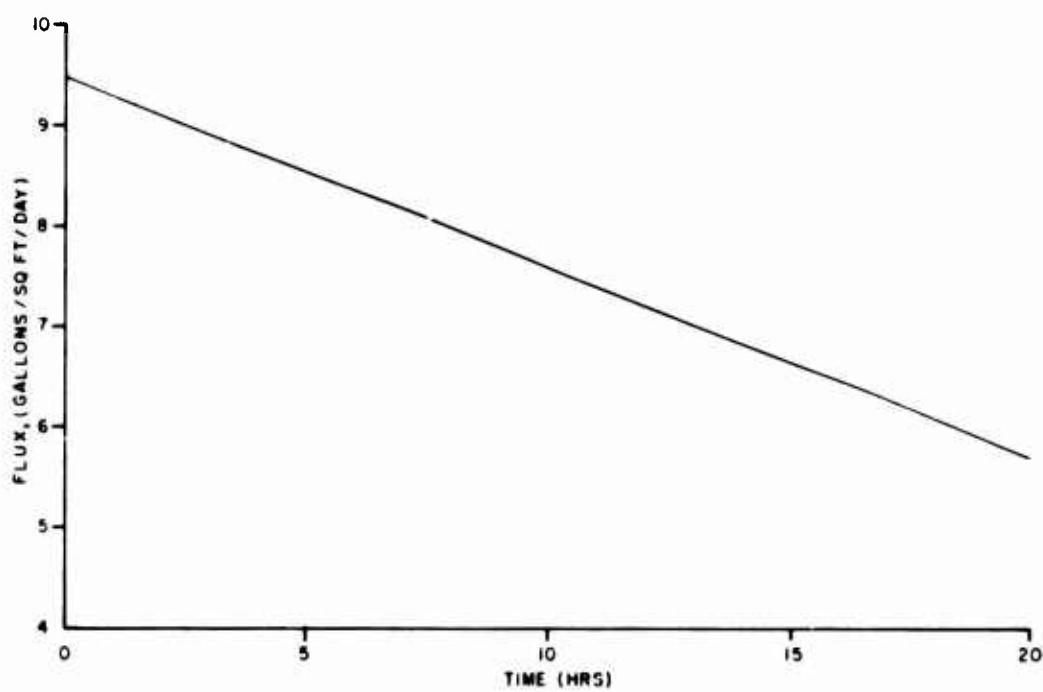


Figure 8. Flux (GF^2D) vs Time (hr), Cellulose Acetate RO Membrane.

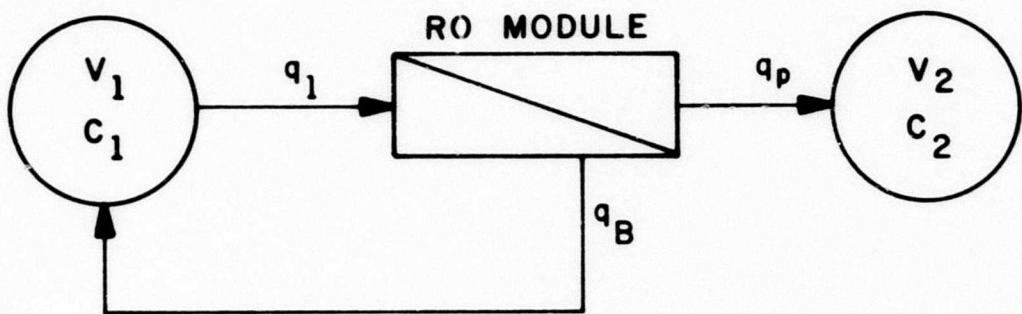
The data presented on the SPPD membranes (Table 9) showing the flux and rejection rates, although not given the type of analysis as that shown for the cellulose acetate, appear to be most enlightening. It is noted that significant progress has been made in the G.E. contract. Formulating, casting, and the fabricating of spiral-wound modules has been completed for extensive testing in the scaled-up pilot plant operation noted earlier. During this next phase, rigorous exposure and analysis of the observed data will be accomplished on both these SPPD and other cellulose-acetate spiral-wound RO modules. Therefore, further discussion regarding the SPPD membrane is postponed until completion of the next phase of the project.

IV. CONCLUSIONS

6. Conclusions. Based on the data obtained in the laboratory phase of this study and subject to that data generated in the pilot plant phase, the following conclusions appear valid:

- a. The application of cellulose-acetate and modified sulfonated polyphenylene oxide RO membranes as a unit process in the treatment of dilute acid wastewaters generated at RAAP is technically feasible.
- b. The concentration of nitric and sulphuric acid at acceptable rates for engineering scale-up using RO is feasible and attainable.
- c. The permeation or flux rates attainable in the treatment of RAAP acid wastewaters are acceptable for engineering scale-up.
- d. Hydrolysis of the cellulose-acetate membrane did not significantly impair the performance characteristics of the RO modules.
- e. Acidic corrosion of the metallic components of the RO system can introduce operational problems that will significantly interfere with the rejection and flux rates of the RO membranes.
- f. Continuation of the program into a Phase II RO pilot plant operation located at RAAP for on-site evaluation and performance documentation and/or verification is justified.

APPENDIX A
REJECTION MODEL MATHEMATICS



Definitions:

V_1 = fluid volume in tank 1

V_2 = fluid volume in tank 2

C_1 = concentration in tank 1

C_2 = concentration in tank 2

q_1 = fluid flow rate in - $\frac{dV_1}{dt} = K$

q_p = product flow rate = $\frac{dV_2}{dt}$

q_B = brine flow rate

t = time

C_{10} = C_1 at $t=0$

V_{10} = V_1 at $t=0$

α = rejection percentage rate

Consider Single Species Only

balance on 1 is:

$$(1) \quad q_1 * C_1 = V_1 C_1 - q_p * C_1 + q_B (1 - \alpha) C_1$$

balance on 2 is:

$$(2) \quad q_p * C_2 = q_1 * C_1 - q_1 * \alpha * C_1$$

$$(2a) \quad \frac{d}{dt} V_2 * C_2 = K C_1 - K \alpha C_1$$

from continuity: $q_1 = q_p + q_B \quad (3)$

$$V_1 + V_2 = V_{10} \quad (4)$$

Overall balance on the system:

$$C_1 V_1 + C_2 V_2 = C_{10} V_{10} \quad (5)$$

$$\frac{C_1 = C_{10} V_{10} - C_2 V_2}{V_{10} - V_2} \quad (6)$$

Now differentiate (2a) and obtain

$$(2b) \quad V_2 \frac{dC_2}{dt} + C_2 \frac{dV_2}{dt} = K C_1 - K \alpha C_1$$

$$(2c) \quad = K C_1 (1 - \alpha)$$

Substitute (6) into (2c)

$$V_2 \frac{dC_2}{dt} + C_2 \frac{dV_2}{dt} = K \left[\frac{C_{10} V_{10} - C_2 V_2}{V_{10} - V_2} \right] [1 - \alpha]$$

Let $\Delta = V_{10} - V_2$

$$\alpha_\tau = 1 - \left[\frac{C_2 * \frac{dV_2}{dt}}{K[\Delta]} \right] - \left[\frac{V_2 * \frac{dC_2}{dt}}{K[\Delta]} \right]$$

APPENDIX B

PROGRAM C10C0NE C10C0NE 74574 OPT=1
 FORTRAN PROGRAM - REFLECTION MODEL
 F16 4.1+PSR367 67/3974 11.25.14. PAGE 1

PROGRAM C10C0NE(INPUT,OUTPUT,TAP0E1=INPLT,TAP0E2=OUTPUT,TAP0E3,TAP0E4)

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COMMON/XMAX/X(1500,2)
COMMON/XMAX/PALENX(5), XIMP(500,5)
5 COMMON/YMAX/YLEN(Y(97,YINCSC,9));
COMMON/TRANS/TPLG(7),IMODL
COMMON/IWHICH/IWHICH,IYWHICH,IYWHICH,IXSRT,IYSRT,ICURVE,IORD,N,ISEGNU,ICONT
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COMMON/XTITLE/XTITLE(16,5)
COMMON/YTITLE/YTITLE(8,16)
COMMON/HEAD/UNIT(3),IPTRR,3),RPSI
COMMON/AXES/YMIN(10),YMAX(10),YMIN(10),YMAX(10),XLLEN(10),
1YLEN(11),DELTAX(10),DELTAY(10)
COMMON/SEONS/NCURVE(10),NORDER(2),COEFFS(8,11)
COMMON/DERIVA/YPRE(500,6),XPRE(500)IPRE,QVOLCON
15 DIMENSION STATS(6)
DIMENSION CC(11)
DIMENSION YL(500),YL(500),P(500),R(500),YP(500),RES(500),X0UM(500)
DIMENSION SSR(5)*B(2),AINV(4),C(4),S(2),IAUFL(1000)
DIMENSION MMWHCH(12),MMWHCH(2)/8,4/
DATA ISHT/1/
DATA (X(1,1),I=1,500)/500*1.0/
20 DATA (Y(1,1),I=1,500)/500*1.0/

```

25 THIS PROGRAM IS AN EXPONENTIAL CURVE FIT USING REGRESSION ANALYSIS
 26 N IS NUMBER OF OBSERVATIONS

27 INPUT SECTION
 CARD INPUT DECK STRUCTURE
 1 MONT,DAE,YEAR,CYCLE (A5,3F10.4)
 2 DAY,YEAR,CYCLE APPROPRIATE MONTH ABBREVIATION
 3 5 CHARACTER UNIT TITLE (3A10)
 4 IPUF,IMODL (212) 01..YES PLOT, 02..NO PLOT, 03..NO MODEL, 04..YES MODEL
 6 XMAX,AXLEN(IPCJ),YMIN(IPCJ),YMAX(IPCJ),YMIN(INFLUX),YMAX(INFLUX)
 YMAX MAXIMUM EXPECTED CUMULATIVE TIME
 AXLEN INCHES DESIGNED FOR THE Y AXIS, MAXINUR IS 10.
 YMIN LEAST Y VALUE
 YMAY GREATEST Y VALUE
 7 NUMBER OF X DATA POINTS (15)
 8-A N = X_i DATA POINTS (F15.4)
 9 THE ENTIRE SET OF CUMULATIVE TIME DATA IS READ HERE
 10 IWHICH,ISCHNU,ICONT,IXST,4,ICURVE (615)
 11 IMWHC 51..TURBIDITY-CGAG, 52..TURBIDITY-FILTER..SPECIFIES KIND OF DAT
 ISEGNU SEGMENT NUMBER USED IN KEY
 ICOUNT 11..THIS DATA IS NOT THE LAST Y SET CORRESPONDING TO X
 12..GET THE NEXT X DATA SET AFTER PROCESSING THIS Y DATA SET
 IXST ARRAY INDEX OF FIRST X CORRESPONDING TO THE FIRST Y OF THIS
 SEGMENT
 13 NUMBER JFY Y DATA POINTS IN THIS SEGMENT
 ICURVE 51..EXPONENTIAL FIT, 52..POLYNOMIAL CURVE FIT
 INKJ IS THE ORDER OF THE POLYNOMIAL
 NLGAF,NUGAF (215)
 14 NLGAF J1..PUT THIS DATA ON A NEW FRAME, 92..SAME FRAME

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2  NUAXIS 51. DRAW A NEW Y AXIS. 52. STAY ON THE OLD AXIS
3  4 - Y DATA CARDS (F10.4)
4  DD XTITLE,YTITLE,YKEY,YKEY,RKMG (6F10.4)
5  THIS CARD IS ONLY NECESSARY AFTER A NEW FRAME HAS BEEN REQUESTED
6  XTITLE,YTITLE,RKMG SIZE AND LOCATION OF TITLE HEADING
7  XKEY,YKEY,RKMG SIZE AND LOCATION OF THE GRAPH KEY AND LINE EQUATIONS
8  SEGMENT DATA SETS CONSIST OF CARDS B,C,D, AND POSSIBLY DD
9  COMPLETE DATA SET CONSISTS OF CARDS 2,3,4,5,6,7,8,A, AND ANY E SE'S
10 COMPLETE RUN SET REQUIRES CARD 1 AT THE TOP

11 MONT=SHIFT(DATE(I,J),6)
12 ITIME=SHIFT(TIME(I,J),6)
13 WRITE(4,380)
14 FORMAT(1M1)
15 READ(4,380)
16 FORMAT(1M1)
17 DO 125 I=1,5
18 READ(1,121) (XTITLE(J,I),J=1,49)
19 FORMAT(4A10)
20 IF(EOF(1)) 501,120
21 CONTINUE
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INTERFRAME
CICCONF 76/74 CPT=1

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PROGRAM UTCNONE 76/74 OPT=1
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```

    WRITE(6,15) MONT,ITIME,IFRAME
    75 FORMAT(16.4,DATE*,A10*,TIME*,A10*, FRAME NO. *,I4)
    WRITE(6,15) IXWHCH,IYWHCH,IXSRT,IYSRT,ICURVE,IORD,N,ISEGNN,ICONN
    175      ,NUGRAF,NUAXIS
    43 FORMAT(* I15, I15,
    3* ICURVE * I15,
    1* IORD * I15, N * I15, ISEGN * I15, IYSRT * I15, I15,
    2* NUAKIS * I15)
    16-    WRITE(2,36) IUNIT
    FORMAT(16.6,A1C)
    WRITE(2,26) IRTTP
    WRITE(6,39) XMIN(IXWHCH),XMAX(IXWHCH),YMIN(IYWHCH),YMAX(IYWHCH),XL
    1EN(IKWHCH),YLEN(IYWHCH),DELTAX(IKWHCH),DELTAY(IYWHCH)
    195      FOR4AT(* XMIN *, XMAX *, F10.4,*, YMIN *, F10.4,*, YMAX *, F
    11.4/
    1* XLEN *, F10.4,*, YLEN *, F10.4,*, DELTAX *, F10.4,*, DELTAY *
    2, F10.4)
    WRITE(2,36) (XTITLE(JJJ,IXWHCH),JJ=1,4), (YTITLE(KK,IYWHCH),KK=1,3)
    34 FORMAT(1X,4A10, VS*, 3A10/T3,* X VALUE*,I15,* Y VALUE *,I15,* T29,
    1* PREDICT Y VALUF*,T45,*RESIDUAL*)
    33 WRITE(2,5) (X(I,2),Y(I),RES(I),I=1,N)
    IF(INXTRP.NE.0) WRITE(2,261)(X(N+I,2),YP(N+I),I=1,MNXTRP)
    266 FORMAT(1H ,1X,F8.4,23X,F8.1)
    WRITE(2,6) N
    IF(INXTRP.NE.0) WRITE(12,269) MNXTRP,DLXTRP
    269 FORMAT(* NUMBER OF EXTRAPOLATED POINTS IS *,I9,2X,*EVERY *,F10.4,
    1* UNITS*)
    271      GO TO (28,29),ICURVE
    28      WRITE(2,9) SSR(1)
    WRITE(2,10) SSR(2)
    WRITE(2,11) SSR(3)
    WRITE(2,12) SSR(4)
    WRITE(2,13) S
    13  FORMAT(1H0,2X,*EQUATION IS OF THE FORM Y = A EXP(B X) WHERE A = *,*
    1E15.5,3X,* AND B = *,E15.6)
    GO TO 31
    29      WRITE(2,12) SSR(4)
    WRITE(2,14)
    14  FORMAT(1H*,2X,*EQUATION IS OF THE FORM Y = C(1)*X**IORD+...+C10
    1R0+1)
    DO 21 I=1,IORD
    210 IDIND = IORD-I+1
    IF(IDIND.EQ.1) GO TO 215
    WRITE(2,205) C(I),IDIND
    FORMAT(* WHERE Y = *,(I11,3W + ,E15.6,6W *X** ,I21))
    GO TO 221
    215      WRITE(2,206) C(I)
    206 FORMAT(I11,3W + ,E15.6,3W *X)
    201 CONTINUE
    WRITE(2,222) C(IORD+1)
    222 FORMAT(I11,3W + ,E15.6)
    223      1 FORMAT(1H*,16,*SANITARY SCIENCE DIVISION REVERSE OSMOSIS*)
    2 FORMAT(1H*,16,*DATA ANALYSIS*)
    3 FORMAT(1H*,16,*SUM MINS,T15,*TURBID(CONG)*,T29,*PREDICT T-COAG*),
    1 T45,*RESIDUAL*)
    5 FORMAT(1H ,1X,FA,1,6X,F8.1,9X,F8.1,6X,F9.1)
  
```

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6 FORMAT(1H0,EX,NUMBER OF OBSERVATIONS IS",I4)
7 FORMAT(1H0,2X,"SS OF RESIDUALS IS",F2,X,E15.6)
8 FORMAT(1H0,2X,"SS ABOUT MEAN IS",F2,X,E15.6)
9 FORMAT(1H0,2X,"ESTIMATE OF ERROR VARIANCE IS",F15.6)
10 FORMAT(1H0,2X,"SQ MULT COEF IS",I3,I3,I3)
11 FORMAT(1H0,2X,"STATISTICS ABOUT THE Y INPUT ARE",
12 FORMAT(1H0,2X,"MEAN = ",F11.5,
13 FORMAT(1H0,2X,"SECOND MOMENT = ",F11.5,
14 FORMAT(1H0,2X,"THIRD MOMENT = ",F11.5,
15 FORMAT(1H0,2X,"FOURTH MOMENT = ",F11.5,
16 FORMAT(1H0,2X,"VARIANCE = ",F11.5,
17 FORMAT(1H0,2X,"STANDARD DEVIATION = ",F11.5,
18 FORMAT(1H0,2X,"SKEWNESS = ",F11.5,
19 FORMAT(1H0,2X,"KURTOSIS = ",F11.5)

20 WRITE(12,17) STATS
21 WRITE(12,17) STATISTICS

225 C PLOTTING SECTION
235 C
245 C
255 C
265 C
275 C
285 C
295 C
305 C
315 C
325 C
335 C
345 C
355 C
365 C
375 C
385 C
395 C
405 C
415 C
425 C
435 C
445 C
455 C
465 C
475 C
485 C
495 C
505 C
515 C
525 C
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545 C
555 C
565 C
575 C
585 C
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605 C
615 C
625 C
635 C
645 C
655 C
665 C
675 C
685 C
695 C
705 C
715 C
725 C
735 C
745 C
755 C
765 C
775 C
785 C
795 C
805 C
815 C
825 C
835 C
845 C
855 C
865 C
875 C
885 C
895 C
905 C
915 C
925 C
935 C
945 C
955 C
965 C
975 C
985 C
995 C

```

```

XGUM(I+N)=X(I+I*2).
IF(XDUM(I+N).LT.XMAX(IXMCM)) XGUM(I+N)=XMAX(IXMCM)
IF(XDUM(I+N).LT.XMIN(IXMCM)) XGUM(I+N)=XMIN(IXMCM)
IF(YP(I+N).LT.QMIN) YP(I+N)=QMIN
290   701  IF(YP(I+N).GT.QMAX) YP(I+N)=QMAX
      XDUM(MNMXTRP+1) = XMIN(IXMCM)
      XGUM(MNMXTRP+2) = DELTAX(IXMCM)
      YP(MNMXTRP+1) = YMINTYMC
      YP(MNMXTRP+2) = DELTAY(IYMCM)
      CALL LINE(XDUM,YP,MNMXTRP,1,1.3*YMINTYMC)
      CALL CALCM(41,510,9,10A1T,3)
      CALL EQNRATKKE*PKHAG,PKKEY,RKHAG,B,XDUM(1),XGUM(1),CC1
      YKEY = PKKEY
      GO TO 105,ICONT
105
C      THIS IS THE MODEL SECTION UNDER LTB CICCONES CARE
C
500   801  READ(1,81) ISWD,1IMPUR,PK,TIMF,NOINC,FIMP
      FORMAT(215,3F10.4,15,F10.6)
      WRITE(1,83) ISWD,1IMPUR,DVOLCON,PK,TIMF,NOINC,TIMF
      81   81   FORMAT(14,83) ISWD,1IMPUR,DVOLCON,PK,TIMF,NOINC,TIMF
      83   83   FORMAT(14,83) ISWD,1IMPUR,DVOLCON,PK,TIMF,NOINC,TIMF
      1. 9K +,F9.4,  TIMF +,F10.4, NOINC +,F10.4
      LPRE*NOINC+1
      XPRE(1)*TIMF
      DELT=(TIMF-TIMF)/NOINC
      DO 76 I=1,NOINC
      75   XPRE(I+1)=XPRE(I)+DELT
      CALL CALFON(3)
      IF(1IMPUR.EQ.2) GO TO 90
      CALL CALEEN(1)
      CALL DERIV(1)
      IF(1IMPUR.EQ.1) GO TO 91
      31   31   CONTINUE
      CALL CALEEN(2)
      CALL DERIV(2)
      IF(1IMD-EQ.1) GO TO 92
      CALL DERIV(3)
      GO TO 93
      32   32   CONTINUE
      CALL DERIV(4)
      0.3  0.3  CONTINUE
      JSMT=1
      JJINR=NCURVE(7)
      GO TO (150,151),JJINR
      V1=COEFS(7,1)*EXP(TIM*COEFS(7,2))
      315  151  JJO=JORD-P(7)+1
      V1G=L
      0.153 J=1,JJORD
      V1=V1+COEFS(7,J)*(TIN**((JJORD-JJ))+1)
      152  152  CONTINUE
      IF(V1MPU.NE.3) GO TO 45
      JSMT=2
      1MFJR=1
      1LIM=NOINC+1
      MPOINT=MWCH(1IMPU)
      JJINR=NCURVE(1MPDNT)
      335  153  CONTINUE
      45

```

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PAGE 7
 F7N 4.1.0PSR367 07/39/74 11.28.14.
 P356014 CICCONC 74/74 OPT=1

```

      GO TO (162,163),JJINP
      C1=C0EFFS(MPOINT,1)*FXP(TIMH*COEFFS(MPOINT,2))
      GO TO 164
      JJORD=NORDFP(MPOINT)+1
      CJR=1.
      DO 165 JJ=1,JJORD
      C1=C1n+C0EFFS(MPOINT,JJ)*(T1MP*(JJORD-JJ))
      CONTINUE
      L=I*PUR+1
      DO 166 I=1,TIMH
      CONST=RK*(C1-V10*YPRE(I,IMPUR)*YPRE(I,3))
      Y(I)=( 1-(YPRE(I,IMPUR)/CONST)*YPRE(I,6))-(YPRE(I,3))/CONST*YPRE(I,I
      *PUR+3))+105.
      CONTINUE
      WRITE(12,2)
      WRITE(12,3)
      IFRAME=FRAME+1.
      WRITE(12,35) MONT,ITIME,IFPAME
      WRITE(4,301)
      WRITE(4,35) MONT,ITIME,IFRAME
      WRITE(12,36) IUNIT
      WRITE(12,36) IFRTR
      IF(RPSI.NE.0.)
      *WRITE(12,9698) RPSI
      3699 FORMAT(*,PF10.4,* PSI*)
      WRITE(12,48) XTITLE(J,1),J=1,4, (VTITLE(J,8+IMPU), J=1,3)
      48 FORMAT(T5*1M* VS *3A15)
      WRITE(12,95) (YPRE(J),YPRE(J,IMPUR),YPRE(J,3),YPRE(J,3+IMPUR),
      1YPRE(J,6)),Y(J),J=1,TIMH
      95 FORMAT(T9,*TIME,T25,*CP*,T40,*V2*,T54,*DCP*,T69,*DV2*,T82,
      1*PERC R&J//65X,F1C.""))
      PRINT 166,C0,V10
      FORMAT(//, C10 = *G16.4,* V10 = *,618.4//)
      XPRE(TLIM+1)=XMIN(IMUF+6)
      XPRE(TLIM+2)=DELTA(XIMUF+6)
      GO TO (96,46),TPLOT
      36 CONTINUE
      WRITE(4,37) XMAX(1),XMIN(1),YMAX(L),YMIN(L),YLEN(L),
      1DELTAX(1),DELTAY(L)
      READ(1,111) XYL,YYL,TMAG
      WRITE(12,112) XYL,YYL,TMAG
      IXWHC=1
      375 16P
      CALL CALCP(0, IDAK(1),3)
      CALL BOPNRP(0,0,17*11,1)
      CALL CALCP(0,0, IDAK(1),3)
      CALL DFRM(1,0,5,10,1,14)
      CALL CALCP(1,5,6,5, IDAK(1),3)
      CALL AXIS(0,0,XTITLE(1,IXWHC),-4,0,XLEN(IXWHC),r.,,XMIN(IXWHC),
      *DELTAX(IXWHC))
      CALL SCALE(YYLEN(L),TLM,1)
      CALL HADIXTIL(YYL,TMAG)
      WRITE(12,16) Y(LIM+1),Y(TLM+2)
      385 16 FORMAT(IX* VSTART = *F16.4,* DELTAV = *F13.6)
      CALL AXIS(0,0,XTITLE(1,L),3,YLEN(L),98.,Y(LIM+1),Y(TLM+2))
      CALL CALCP(1,5,5, IDAK(1),3)
      CALL LINE(YPRE, YLIM,1,6)
      GO TO (61,67),JSWT
  
```

P>065211 CICONE^E 74774 OPT=1
FTN 6.1+PSRJ67 07/09/74 11.28.14. PAGE 0

```
        IMPUR=2
        JSWT=1
        GO TO 45
39      GO TO (11,J,102),JSWT
C      CLOSE THE PLOT TAPE IF OPENED
C      CALL CALCP(6.,R,.9999,2)
102     STOP
103     END
```

118 SUBROUTINE READIN 71/74 (P7=1)

F7N 4.1+PSR367

07/09/74 11.26.34s PAGE 1

```
SUBROUTINE READIN,RETURNS(IODAV1,IODAV2)
COMMON/XINP/LEN(9),YINP(500,9)
COMMON/TRANSF/PILOT,IMODL
COMMON/MEO/DUM(-13),RPRTR(3),RPSI
COMMON/AXES/XMIN(10),YMAX(10),YMIN(10),XLEN(10),
YLEN(10),DELTAY(10),DELTAX(10)
READ(11,IU11,IOUT,IPL0,IMODL,REP1)
FORMAT(REAL/3A1C/2I2/F1.4)
IFEOF(11)2,3
2 RETURN IODAV2
3 GO TO 6,IOUT,IPL0
4 READ(11,YMIN),XMAX(11),YMAX(11),YMIN(11),XLEN(11),YLEN(11)
IFEOF(11)5,22
5 FORMAT(6F1.4)
IFEOF(11)5,22
CONTINUE
6 IF(XLEN(1).EQ.8.) XLEN(1)=15.
IF(YLEN(1).EQ.8.) YLEN(1)=10.
DELTAX(1)=YMAX(1)-YMIN(1)/XLEN(1)
CONTINUE
CONTINUE
7 READ IN THE X VALUES
00 9 I=1,5
J=1
READ(11,XINP(J,1))
IF(EQOF(11)) 9,10
IF(IMODL.EQ.6) GO TO 40
11 IF(I.NE.2) GO TO 20
IF(XINP(1,2).EQ.0.) GO TO 20
XINP(1,4)=XINP(1,2)/XINP(1,2)
CONTINUE
12 IF(I.NE.3) GO TO 35
IF(XINP(1,1).EQ.0.) GO TO 30
XINP(1,3)=XINP(1,2)/XINP(1,2)
CONTINUE
13 J=J+1
GO TO 9
14 LENX(1)=J-1
IF(IMODL.EQ.5) GO TO 21
LENX(2)=LENX(2)
LENX(3)=LENX(3)
CONTINUE
21 READ IN THE Y VALUES
00 11 I=3,9
J=1
IF(EQOF(11)) 11,13
12 READ(11,YINP(J,1))
IF(I.NE.1) GO TO 12
YINP(1,1)=J-1
RETURN IODAV1
END
```

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SUBROUTINE HEAD	7474	OPT=1	FTN 4.1+P92167	07/09/74	11.29.30.	PAGE 1
<pre> SUBROUTINE HEAD(X,Y,RHAG) COMMON/RHAG/UNIT(3),IPRTR(3),RPSI CALL SYMBOL(X,Y,RHAG,RHAG,6HUNIT),0.,0.) CALL SYMBOL(999.,999.,RHAG,TUNIT,0.,0.) CALL SYMBOL(X,Y-.62,RHAG+.31),RHAG,IPRTR),0.,0.) 5 CALL SYMBOL(999.,999.,RHAG,IPRTR),0.,0.) IF(RPSI.EQ.0.) GO TO 2 CALL SYMBOL(999.-(.3-.7*HAG),.61),RHAG,RPSI),0.,0.) CALL NUMBER(999.,999.,RHAG,RPSI),0.,0.) CONTINUE RETURN END </pre>						

SUBROUTINE EQNRRA 74/74 OPT=1

FTN 4.1•PSR367 C77974 11.26.42. PAGE 1

```
SUBROUTINE EQNRRA(X,Y,FMAC,B,XLO,XHI,C)
DIMENSION L(113)
COMMON/WHICH/IXWHICH,7,WHICH,IXSRI,IVSRT,ICURVE,IORD,N,ISEGMS,ICONT
5      CALL SYMBOL(X,Y+,0,RMAC,RMAC,13-IVWHICH-ISEGMS,0,0,-1)
      GO TO 1,23 JCURVE
1      CALL NUMBER(999.,999.,0,RMAC,0,RMAC,6M Y = .0,.6)
      CALL SYMBOL(999.,Y,RMAC,6M
1)      CALL SYMBOL(999.,999.,0,RMAC,0,RMAC,6M Y = .0,.6)
      CALL SYMBOL(999.,999.,0,RMAC,5M EXP(.0,.3)
      CALL NUMBER(999.,999.,0,RMAC,5M EXP(.0,.3)
      CALL NUMBER(999.,999.,0,RMAC,0(2),0,0,.3)
      CALL SYMBOL(999.,999.,0,RMAC,3M X1,0,0,.3)
      GO TO 1
      ON 4 I=1,INRD
      INRD = IORD-I+1
      RINDJ = INRD
15      CALL SYMBOL(999.,999.,0,RMAC,1M(.0,.3)
      CALL NUMBER(999.,999.,0,RMAC,C(1),0,0,.3)
      CALL SYMBOL(999.,999.,0,RMAC,7M) X0,0,.3)
      TF(INDJ,EQ,1) GO TO 5
      CALL NUMBER(999.,Y+(IPAG/2.),C(PAG/2.),RINDD,0,0,-1)
      CALL SYMBOL(999.,Y,RMAC,3M + ,0,0,.3)
      CONTINUE
      CALL SYMBOL(999.,999.,0,RMAC,1M(.0,.3)
      CALL NUMBER(999.,999.,0,RMAC,C(IORD-1),0,0,.3)
      CALL SYMBOL(999.,999.,0,RMAC,1M(.0,.3)
      3      CALL SYMBOL(999.,999.,0,RMAC,5M 1 0,0,.5)
      CALL NUMBER(999.,999.,0,RMAC,XLO,0,0)
      CALL SYMBOL(999.,999.,0,RMAC,3M-X-.3)
      CALL NUMBER(999.,999.,0,RMAC,XHI,0,0)
      CALL SYMBOL(999.,999.,0,RMAC,1M<,0,0,.3)
      RETURN
END
```

SUBROUTINE KRY 74/74 OPT=1

FTN 4.1+PSR367 C7/69/74 11.28.66.

PAGE 1

```
SUBROUTINE KRY(X,Y,RHAG,IYWHCH)
COMMON/YTITLE/YTITLE(15,10)
CALL SYMBOL(X,Y+.5,RHAG,RHAG,IYWHCH-1,0.,-1)
CALL SYMBOL(199.,Y,RHAG,22H EXPERIMENTAL VALUES),0.,,22)
CALL SYMBOL(699.,999.,RHAG,YTITLE(1,IYWHCH),0.,38)
5   Y = Y - (RHAG + .14)
    CALL SYMBOL(X,Y,RHAG,31H      PREDICTED VALUE EQUATION(3),0.,31)
    Y = Y - (RHAG + .16)
RETURN
END
```

1.

Subroutine: `ROGFL`

FIN #.1693#307 07/09/74 21.29.58. PAGE 3

```
      SUBROUTINE ROGFL (X1,YC,X1,Y1)
      NEW FRAME
      CALL CALCHP(1,0,0,1,0,2)
      0      JPAH LINES
      CALL CALCHP(1,X1,YC,99,1)
      CALL CALCHP(1,X1,Y1,99,1)
      CALL CALCHP(1,X1,Y1,99,1)
      CALL CALCHP(1,X1,Y1,99,1)
      CALL CALCHP(1,X1,Y1,99,1)
      RETURN
      END
      5
      13
```

SUBROUTINE IDFRM 74/74 09721
 FTN 4.14PSR367 07/09/74 11.20.57. PAGE 1
 COMMON/DATE/MONT,LTIM,PRIME
 DATA FRAME/-1./
 FRAME = FRAME + 1.
 CALL SYMBOL(X,Y,XMAC,AMODE) 1.
 CALL SYMBOL(999,999,XMAC,MONT,0,0)
 CALL SYMBOL(X,LY,L7+XAG) XMAC,10NAME) LTC, CIGCONE,0,10)
 CALL SYMBOL(X,LY,14*2,XAG) XMAC,SPHAGRAM, CIGCONE,0,15)
 CALL SYMBOL(X,LY,21*3,XAG) XMAC,TTMF, 9,9)
 CALL SYMBOL(999,999,XMAC, SMFRA) ;0,,9,
 CALL NUMBER(999,999,XMAC,FOANE,0,-1)
 RETURN
 END

SUBROUTINE POLYFIT 7474 OPT=1

FTN 4.1+FS2367 07/33/74 11.29.01.

PAGE 1

```
SUBROUTINE POLYFIT(XXX,Y,N,M,YC,RES,C,SSR)
COMMON/XXX/XXX(5:0,2)
DIMENSION XX(1,1)
DIMENSION A(11,12),B(21),X(250)
5      X,Y ARE INPUT ARRAYS
      N IS THE NUMBER OF POINTS
      M IS THE ORDER OF THE CURVE TO FIT
      YC IS THE PREDICTED Y
      C IS THE COEFFICIENTS
      SSR IS THE SUM OF SQUARES OF RESIDUALS
      RES IS THE ARRAY OF COEFFICIENTS
      Y(200),YC(200),RES(200),C(11),SSR(5)
      IF (NLE.1) STOP
15     IF (NLE.5) GO TO 2
      PRINT 110,N
110    FORMAT(//5X16HNUMBER OF POINTS =,I5,2X16HEXCEEDS MAX. OF 500/
      STOP 1
2     IF (M.GT.3) GO TO 3
      PRINT 120,J
120    FORMAT(//5X9HDEGREE =,I5,9H IN ERROR/5X16HPROGRAM ERROR STOP)
      STOP 2
3     IF (MLE.1) GO TO 4
      PRINT 130,I
130    FORMAT(//5X8HDEGPER =,I5,2X,13HREDUCED TO 10)
      I=10
4     CONTINUE
      5 MA=N+1
      M3=N+2
      M2=N+4
      10 1=1,M2
      11 3(I)=X(I)**I
      12 2=1,M2
      13 0=2,J=2,N
      20 2 J=2,N
      21 8(I)=B(I)+X(J)**I
      22 A(I,MA)=N
      23 0=3,I=2,MA
      24 A(I,MA)=3(I-1)
      25 0=4,I=1,MA
      K=I-1
      0=4,J=2,MA
      L=MA-J+1
      K=K+1
      46 A(I,L)=9(K)
      SUM=0.0
      DO 50 I=1,N
      50 SUM=SUM-Y(I)
      0=6,I=1,M
      61 3(I)=-Y(I)*X(I)**I
      0=7,I=1,M
      DO 75 J=2,N
      75 A(I)=A(I)-Y(J)*X(J)**I
      76 A(I,MA)=SUM
      0=8,I=2,MA
      80 A(I,MA)=3(I-1)
      0=9,I=1,M
      DO 95 K=1,M
```

SUBROUTINE: POLYFIT 74/74 OPT=1

FTN 4.1+FSR367 07/09/74 11.29.91.

PAGE 2

```
L = K + 1
DO 9 J = K, MA
   A(J) = A(I,J,K)
 9   DO 10 I = L, MA
     A(I,J) = A(I,J)/A(I,I)
 10  DO 11 J = K, MA
     A(I,J) = A(K,J) - A(I,J)
    11  A(MA,MA) = A(MA,MA) - A(MA,MA)
    12  DO 13 I = 1, MA
     C(I) = -A(I,MA)
    13  DO 14 J = 2, MA
     K = MA - J + 2
     L = K - 1
    14  DO 15 I = 1, L
     C(I) = C(I) - A(I,K)*C(K)
    15  SUM = 0.0
     SY = 0.0
     SZ = 0.0
    16  DO 15u I = 1, N
     P = X(I)
     Q = P*C(I)
     IF(M.EQ.1) GO TO 145
    14  DO 14 J = 2, M
     14u Q = P*(Q+C(J))
     145 YC(I) = Q + C(MA)
     RES(I) = Y(I) - YC(I)
     SUM = SUM + RES(I)**2
     SY = SY + Y(I)
    15  SZ = SZ + Y(I)**2
    15u SZ = SZ + SY*SY/FLOAT(N)
     SSR(1) = 1.0 - SUM/SZ
    RETURN
END
```

SUBROUTINE DERIV INP
 74 / 74 OPT=1
 FTN 4.1+PSR367 87/09/74 11.29.05. PAGE 1

```

SUBROUTINE DERIV(INP)
COMMON/DERIVA/YPRE(50,50),XPRE(50,50),YPRE,DVOLCON
COMMON/EQNS/NCURVE(6),NORDER(6),COEFFS(6,11)
IF(INP.EQ.4) GO TO 3E
JIND=NCURVE(INP)
GO TO (1,2),JIND
1 DO 3 I=1,LPRE
  YPRE(I,IMP+3)=COEFFS(INP,2)*VPRE(I,IMP)
  RETURN
2 JLIW=NORDER(INP)
SUM=J,0
30 4 I=1,LPRE
  SUM=SUM+COEFFS(INP,J)*(JLIW+1-J)*(XPRE(I,0)*(JLIW-J))
  RETURN
5 DO 5 J=1,JLIM
  SUM=SUM+COEFFS(INP,J)*(JLIW+1-J)*(XPRE(I,0)*(JLIW-J))
  YPRE(I,IMP+3)=SUM
  RETURN
6 DO 6 I=1,LPRE
  YPRE(I,6)=DVOLCON
  RETURN
70
20

```

SUBROUTINE CALCN
 7474 OPR=1
 FTN 4.1+PSR367
 67/03/74 11.29.06. PAGE 1

```

SUBROUTINE CALCN(INP)
COMMON/ZON/NCURVE(18),NORDER(18),COEFFS(9,11)
COMMON/DERIV/YPRE(500,6),XPRE(500),LPRE,OVALCON
JIND=NCURVE(INP)
GO TO 1,JIND
DO 3 I=1,LPRE
  YPRE(I,INP)=COEFFS(INP,I)*EXP(XPRE(I))+COEFFS(INP,21)
  RETURN
2 JLIN=NORDER(INP)+1
DO 4 I=1,LPRE
  SUM=0.0
  DO 5 J=1,JLIN
    SUM=SUM+COEFFS(INP,J)*(XPRE(I)**(JLIM-J))
    YPRE(I,INP)=SUM
  RETURN
4
15
      END

```

APPENDIX C

COMPUTER ANALYSIS - OBSERVED DATA

SANITARY SCIENCE DIVISION - NEVADA NMSIESIS

DATA ANALYSIS TIME 11-32-45. FRAME NO. 1

ACID WASH: WATER RO STUDY

(CUCONNE)

X VALUE	TIME (1-HOURS)	Y VALUE	PREDICT Y VALUE	VS BRINE CONC. - IMPURITY 2
0.0	39.0.1	5676.1	-1676.1	
0.1	59.0.0	5676.1	223.9	
0.2	59.0.0	5676.1	322.9	
0.3	59.0.0	5676.1	723.9	
0.4	59.0.0	5676.1	623.9	
0.5	59.0.0	5943.7	-1643.7	
0.6	59.0.0	5943.7	356.3	
0.7	59.0.0	5943.7	556.3	
0.8	59.0.0	5943.7	-716.9	
0.9	59.0.0	6316.9	-116.9	
1.0	59.0.0	6316.9	263.1	
1.1	59.0.0	6316.9	583.1	
1.2	59.0.0	6795.6	-995.6	
1.3	95.0.0	6795.6	1795.6	
1.4	95.0.0	7379.9	-779.9	
1.5	95.0.0	7379.9	1125.1	
1.6	95.0.0	7379.9	525.1	
1.7	95.0.0	9.69.6	936.2	
1.8	35.0.5	9465.2	734.6	
1.9	31.1.1	9965.2	236.6	
2.0	39.0.0	9766.2	-966.2	
2.1	99.0.3	13772.6	-972.6	
2.2	315.0.3	19772.6	-1772.6	
2.3	117.0.0	1.772.6	227.2	
2.4	145.7.0	11696.9	2115.1	
2.5	12010.0	13102.6	-1102.6	
2.6	13570.0	13102.6	-2652.6	
2.7	172.0.0	16425.9	2974.1	
2.8	175.7.0	17389.0	211.0	

NUMBER OF OBSERVATIONS IS 29

SO MULT CURR COEF IS

.969799E+10

EQUATION IS OF THE FORM Y = C(1)*X**1ORD+...+C(N)*X**NORD+1

WHERE Y = .131954E+32 *X**2

+ .177410E+03 *X

+ .567608E+04

BASIC STATISTICS ABOUT THE Y INPUT ARE

MEAN = 0.669.7

SECOND MOMENT = .1. 845E+0

THIRD MOMENT = .46.74E+11

FOURTH MOMENT = .49642E+15

VARIANCE = .11232E+08

STANDARD DEVIATION = 3.351.4

SKENNESS = 1.2453

KURTOSIS = 1.2211

SANITARY SCIENCE DIVISION REVERSE OSMOSIS
 DATA ANALYSIS
 DATE 6/23/74 TIME 11:32:45. FRAME NO. 2
 ACID WASTEWATER RD STUDY
 (ICICONE)

X VALUE	TIME (HOURS)	PREDICT Y VALUE	VS BRINE CONC. - IMPURITY 1 RESIDUAL
1.1	21.94	2200.9	-200.9
1.1	25.50	2250.9	269.1
1.1	23.10	2280.9	49.1
1.1	25.0.3	2280.9	219.1
1.1	21.90	2260.9	-100.9
2.1	20.40	2310.3	-230.3
2.1	25.0.7	2310.3	169.7
2.1	23.10	2320.3	-1.3
4.1	21.30	2323.0	-293.0
4.1	24.50	2323.0	137.0
4.1	23.56	2323.0	37.0
4.1	24.24	2323.0	97.0
6.1	21.27	2319.1	-292.1
6.1	21.97	2319.1	-129.1
6.1	24.90	2298.4	191.6
9.1	22.30	2298.4	-98.4
9.1	22.36	2298.4	-18.4
15.1	21.63	2261.0	-101.0
12.1	21.75	2207.0	-32.0
12.1	22.30	2207.0	63.0
14.1	21.55	2136.2	16.8
16.0	23.29	2149.7	271.3
16.0	19.91	2048.7	-58.7
16.0	21.90	2048.7	161.3
18.1	10.25	1944.6	-119.6
2.1	21.60	1923.7	336.3
2.1	17.3.9	1923.7	-123.7
22.1	14.95	1686.1	-191.1
26.1	13.10	1360.9	-50.9

NUMBER OF OBSERVATIONS IS 29

SQ MULT CORR COEF IS

.651898E+30

EQUATION IS OF THE FORM Y = C(1)*X**1+C(2)*X**2
 WHERE Y = + .253733E+01 *X**2
 + 183879E+02 *X
 + .223788E+14

BASIC STATISTICS ABOUT THE Y INPUT ARE
 MEAN = 2164.
 SECOND MOMENT = 81316.
 THIRD MOMENT = -.25944E+06
 FOURTH MOMENT = .29940E+11
 VARIANCE = 86.516.
 STANDARD DEVIATION = 290.72
 SKEWNESS = -1.2416
 KURTOSIS = 1.4967

SANITARY SCIENCE DIVISION REVERSE OSMOSIS
 DATE ANALYSTS: TIME 11.32.45.
 DATE 07/39/74 TIME 11.32.45.
 FRAME NO. 3
 ACID WASTEWATER RD STUDY
 (CICCOME)

X VALUE	TIME (HOURS)	PREDICT Y VALUE	PRODUCT CONC. - IMPURITY 1	VALUE RESIDUAL
2.0	21.00.0	2489.5	-309.5	
2.0	27.00.0	2488.5	-210.5	
2.0	25.00.0	2489.5	-100.5	
4.0	23.70.0	2591.9	-501.9	-444
4.0	27.30.0	2551.9	170.1	
4.0	26.10.0	2551.9	50.1	
4.0	26.59.0	2551.9	298.1	
6.0	24.29.0	2685.6	-575.6	
6.0	27.20.0	2684.6	215.6	
8.0	26.20.0	2644.8	195.2	
8.0	25.70.0	2644.8	25.2	
9.0	29.50.0	2644.8	205.2	
10.0	26.49.0	2675.4	-35.4	
12.0	25.50.0	2695.4	-45.4	
12.0	27.20.0	2655.4	24.6	
14.0	26.40.0	2704.6	-66.6	
16.0	27.50.0	2703.7	16.3	
16.0	25.60.0	2703.7	-183.7	
16.0	26.40.0	2703.7	-136.3	
18.0	27.90.0	2692.6	95.0	
20.0	26.60.0	2669.7	288.3	
20.0	22.19.0	2669.7	999.7	
22.0	27.70.0	2636.0	133.2	

NUMBER OF OBSERVATIONS IS 23

SQ MULT CCRR COEF IS .960106E-01

EQUATION IS OF THE FORM Y = C(1)*X**IORD+...+C(IORD+1)
 WHERE Y = + -.132196E+01 *X** 2
 + .391919E+02 *X
 + .241665E+04

BASIC STATISTICS ABOUT THE Y INPUT ARE

MEAN = 2624.7
 SECOND MOMENT = 55250.
 THIRD MOMENT = -.17657E+08
 FOURTH MOMENT = .11925E+11
 VARIANCE = 57752.
 STANDARD DEVIATION = 246.36
 SKENNESS = -1.3442
 KURTOSIS = .57889

SANITARY SCIENCE DIVISION REVERSE OSMOSIS

DATA ANALYSTS TIME 11.32.45. FRAME NO.

ACID MASTICATOR RO STUNY

TURBIDOME

X VALUE	TIME (HOURS)	PREDICT Y VALUE	VS PRODUCT CONC. & IMPURITY %
2.0	300.0	464.0	-166.9
2.9	700.0	468.9	231.1
2.9	500.0	455.8	31.1
4.6	200.0	483.6	-263.7
4.9	420.0	489.6	-61.3
4.7	460.0	483.5	-23.3
4.1	680.0	483.3	196.7
6.9	490.0	501.6	-22.6
6.1	680.0	523.9	576.1
8.1	470.0	523.9	959.9
6.3	620.0	523.9	96.1
10.3	510.0	550.1	-49.1
12.2	560.0	560.2	-28.2
12.2	820.0	580.2	239.8
14.1	540.0	616.3	-74.3
16.1	440.0	632.4	-172.4
16.3	510.0	652.4	-152.4
16.1	950.1	652.4	197.6
16.1	810.0	680.3	193.7
2.1	520.0	740.2	-190.2
2.1	520.0	740.2	-50.2
22.0	950.1	790.2	159.9

NUMBER OF OBSERVATIONS IS 22

SQ MULT COEF IS

.519367E+30

EQUATION IS OF THE FORM Y = C(1)*X+C(2)*X^2+C(3)*X^3+C(4)*X^4

WHERE Y = + .492494E+13 * X + .2 .424067E+1 * X + .459438E+4

BASIC STATISTICS ABOUT THE Y INPUT ARE

MEAN = 375.45

SECOND MOMENT = 30734.

THIRD MOMENT = .95274E+06

FOURTH MOMENT = .25384E+10

VARIANCE = 32147.

STANDARD DEVIATION = 179.44

SKEWNESS = .16012

KURTOSIS = -.15363

SANITARY SCIENCE DIVISION REVERSE OSMOSIS

DATA ANALYSIS DATE 07/09/74 TIME 11.32.45.

ACID WASTEWATER RO STUDY

(CICcone)

X VALUE	TIME (HOURS)	PREDICT Y VALUE	VS. VOLUME IN PRODUCT TANK (GALS.)	RESIDUAL
1.0	0.9	6.9	3.5	-3.5
1.0	1.0	6.9	3.5	-3.5
1.0	1.1	7.1	3.5	-3.5
1.0	1.2	7.3	3.5	-3.5
2.0	2.1	22.5	29.2	-6.7
2.0	2.2	23.8	29.2	-5.4
2.0	2.3	61.0	29.2	31.8
4.0	4.1	45.0	53.9	-8.9
4.0	4.2	45.0	53.9	-8.9
4.0	4.3	38.0	57.9	-34.1
4.0	4.4	35.0	53.9	-16.9
6.0	6.1	57.5	77.6	-20.1
6.0	6.2	17.6	77.6	-60.4
6.0	6.3	7.0	100.1	-30.1
8.0	8.1	119.0	100.1	16.9
8.0	8.2	35.0	193.1	-15.1
10.0	10.1	14.4	121.6	22.4
10.0	10.2	163.0	142.0	21.0
10.0	10.3	121.0	142.0	-21.0
12.0	12.1	1.2	161.4	20.6
12.0	12.2	1.2	179.6	-34.6
14.0	14.1	1.2	179.6	18.6
14.0	14.2	1.2	179.6	-19.6
16.0	16.1	1.2	196.6	3.6
16.0	16.2	198.0	212.9	-27.4
16.0	16.3	1.2	212.9	27.4
18.0	18.1	2.0	235.0	227.9
20.0	20.1	135.5	235.0	7.5
20.0	20.2	24.0	235.0	227.9
22.0	22.1	227.9	235.0	7.5

NUMBER OF OBSERVATIONS IS 27

SO MULT COPI COEF IS

.929821E+30

EQUATION IS OF THE FORM Y = C(1)*X**1+C(2)*X**2+C(3)*X**3+C(4)*X**4

WHERE Y = -.134436E+01 *X**2

+ .131615E+02 *X

+ .345023E+01

BASIC STATISTICS ABOUT THE Y INPUT ARE

MEAN = 111.03

SECOND MOMENT = 5572.7

THIRD MOMENT = .10397E+06

FOURTH MOMENT = .57157E+06

VARIANCE = 57.87.1

STANDARD DEVIATION = 76.473

SKEWNESS = .24992

KURTOSIS = -1.1599